Transverse Long-range Wakefields

- Single bunch - Effects on multiple pass dynamics.

- Multi bunch - Maximum repetition rate.

Long-range transverse wakefield

Single HOM wakefield

$$w_{\perp}(t) = \frac{2c}{\overline{\omega}} \frac{k_{\perp}}{b^2} e^{-t/\tau} \sin(\overline{\omega} t)$$

$$\tau = \frac{2Q}{\omega} \quad and \quad \overline{\omega} = \sqrt{\omega^2 - 1/\tau^2}$$

Total long-range wake

$$\sum_{i=1}^{N\,\mathrm{hom}} \frac{2c}{\overline{\omega}_i} \frac{k_{i\perp}}{b^2} e^{-t/\tau_i} \sin(\overline{\omega}_i t)$$

High order modes list

Frequency (ave. meas.) [GHz]	Loss factor (simulation) [V/pC/m^2]	R/Q (simulation) [Ω/cm^2]	Q (meas.)
TE_{111}-like			
1.6506	19.98	0.76	$7.0 \cdot 10^4$
1.6991	301.86	11.21	$5.0 \cdot 10^4$
1.7252	423.41	15.51	$2.0 \cdot 10^4$
1.7545	59.86	2.16	$2.0 \cdot 10^4$
1.7831	49.20	1.75	$7.5 \cdot 10^3$
TM_{110}-like			
1.7949	21.70	0.77	$1.0 \cdot 10^4$
1.8342	13.28	0.46	$5.0 \cdot 10^4$
1.8509	11.26	0.39	$2.5 \cdot 10^4$
1.8643	191.56	6.54	$5.0 \cdot 10^4$
1.8731	255.71	8.69	$7.0 \cdot 10^4$
1.8795	50.80	1.72	$1.0 \cdot 10^5$
TE-like			
2.5630	42.41	1.05	$1.0 \cdot 10^5$
2.5704	20.05	0.50	$1.0 \cdot 10^5$
2.5751	961.28	23.80	$5.0 \cdot 10^4$

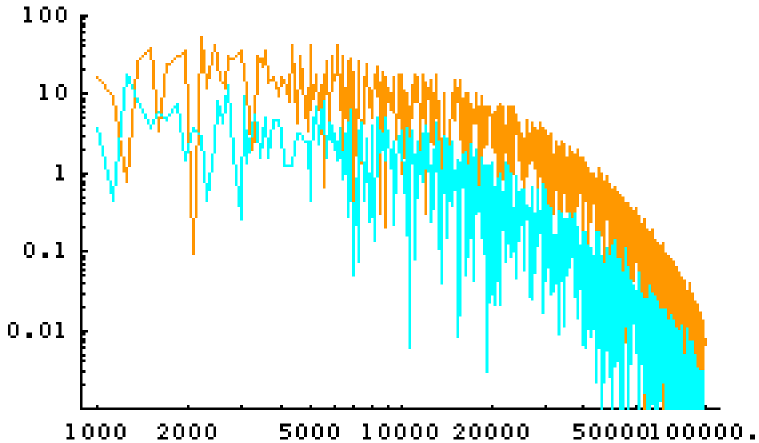
Single bunch - Multiple passes

- Given the high Q's (> 10^4), the wake accumulates pass after pass.
  On the other side, the energy is also increasing making the bunch less sensitive to the wake.
- Since the total wake oscillates, later linac passes are not necessarily subject to a higher wakefield. This means the lower energy pass is still the most critical one.

Effects of random cavity detuning

- A ±1% uniformly distributed spread in the modes frequency reduces the wakefield by a factor of 10. It also makes it depedant on the actual frequency distribution of the assembled linac.

V/pC/m^2

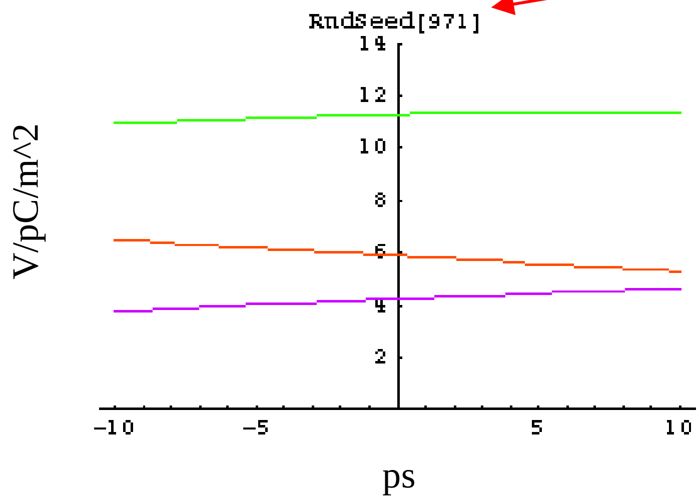


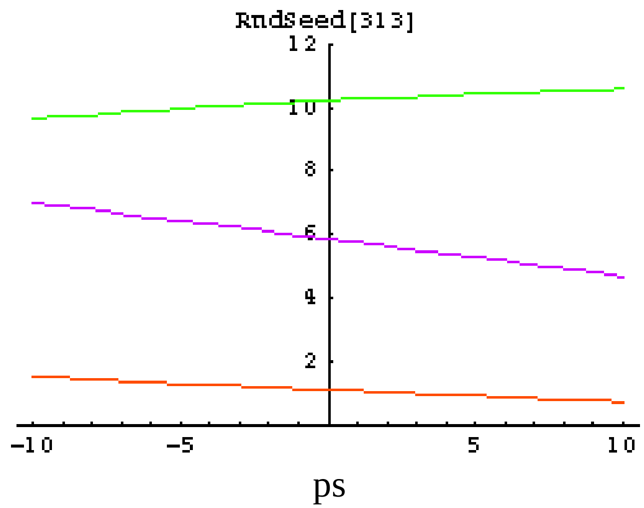
Single pass wake (ns)

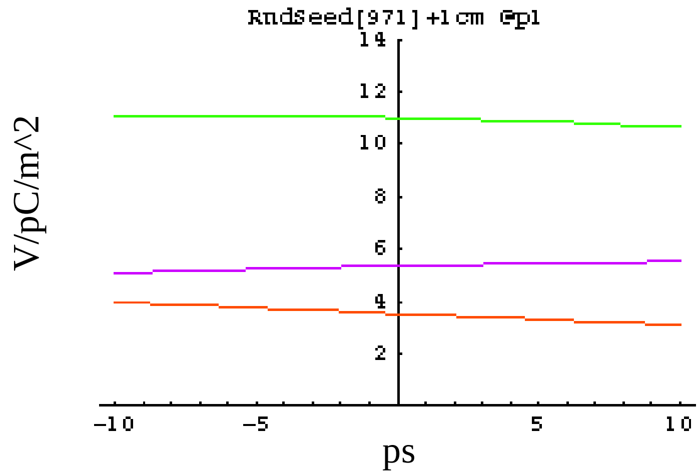
We are mainly interested in the accumulated long-range wakefield on a short timescale (~ ps) at each bunch passage through the linac:

Second pass Third pass Fourth pass

Different random seed in the frequency spread





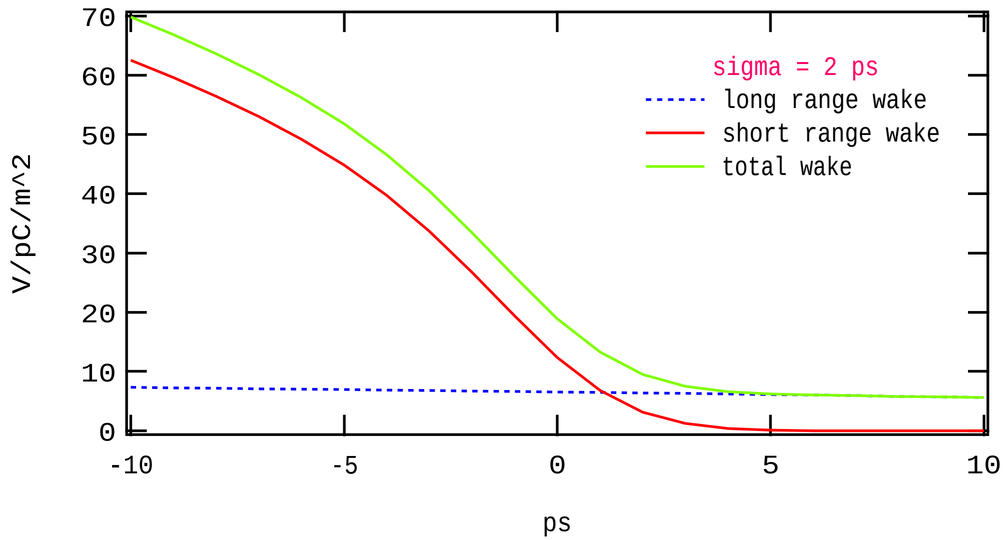


First arc length increased by 1 cm

Total transverse wake

- Compared to the short-range wake, the long-range is not substantially lower, but it is much more uniform over the bunch length.

  This translates into only an additional offset of about 3% the initial injection offset error.



“Very” Long-range transverse wake

- Wake field left in the linac after a single bunch has been recirculated 4 (or 8) times.
- This affects the following bunches and is strictly related to the maximum repetition rate obtainable.
- At the moment we limit the analysis to the case of rep rates lower than ~320 kHz (160 kHz, for the “energy recovery” scheme) so that there are never two bunches being accelerated at the same time.

Again, the long-range wake oscillates, but is fairly constant over the bunch length except in a few unlucky spots.

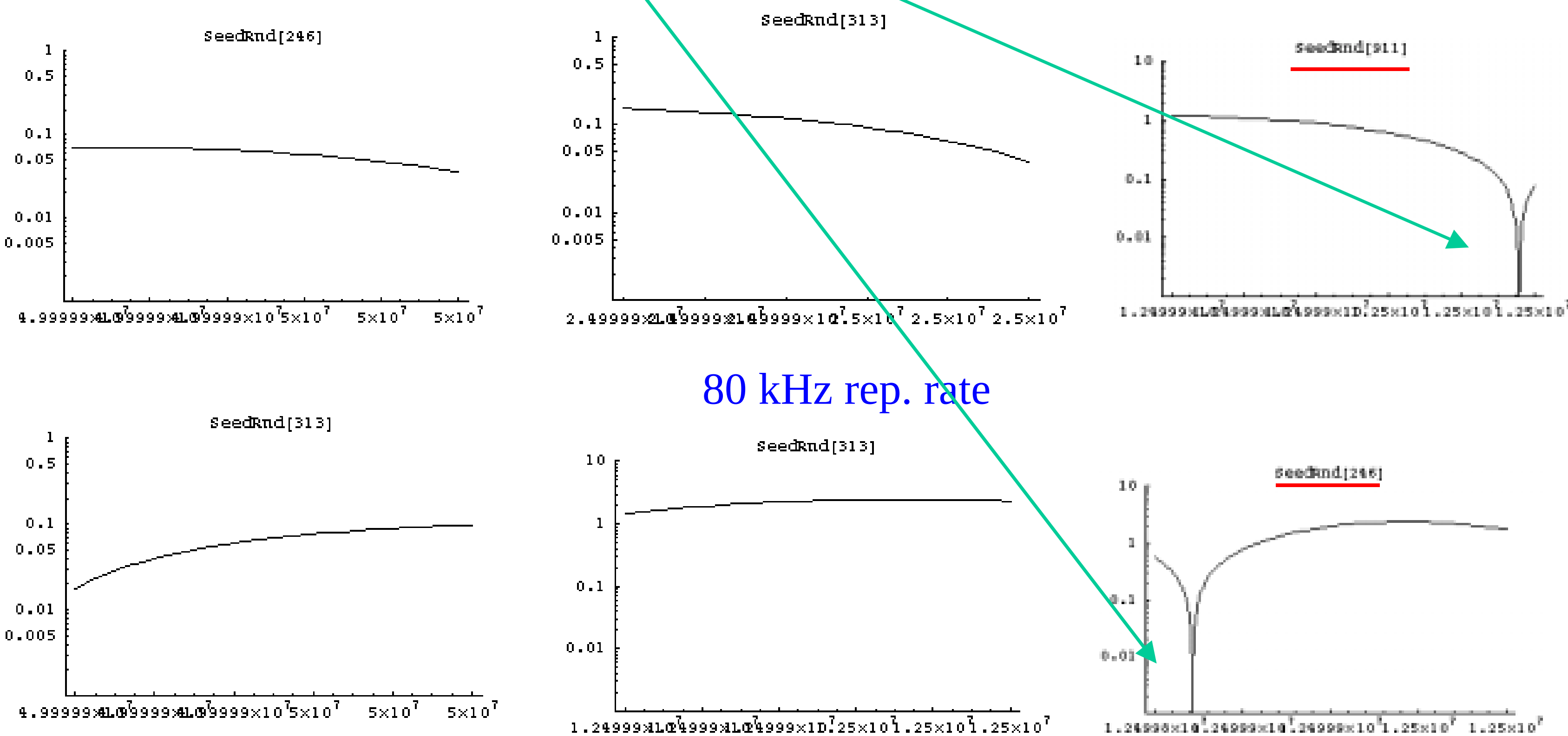
V/pC/m^2

20 kHz rep. rate

40 kHz rep. rate

80 kHz rep. rate

80 kHz rep. rate



100 ps

100 ps

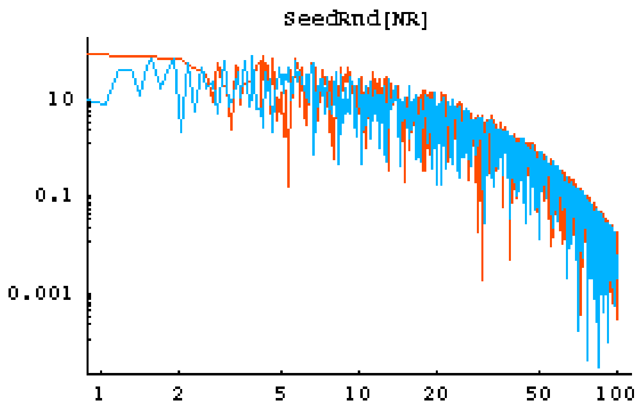
100 ps

S. De Santis - Femtosource 4/10/2002

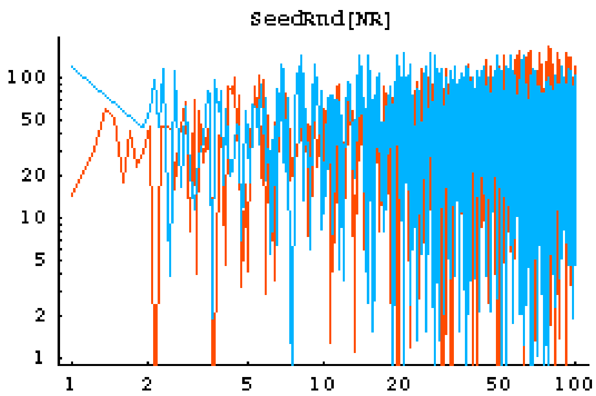
“Energy recovery” scheme

More passes = higher wake ?

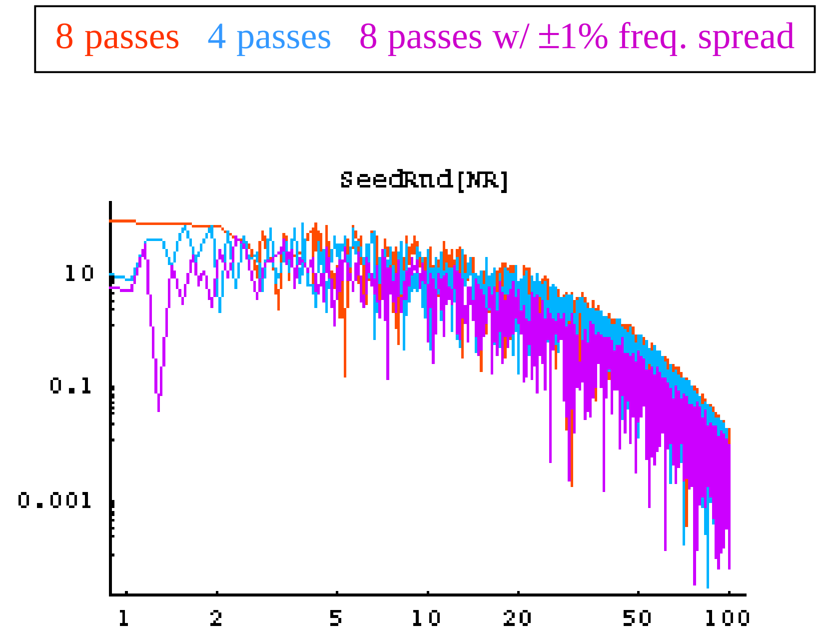
V/pC/m^2



μs



ns



μs